Spring 2006
Industry Study

Final Report
Space Industry

<u>The Industrial College of the Armed Forces</u>
National Defense University
Fort McNair, Washington, D.C. 20319-5062

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Spring 2006 Industry Study Space Industry**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Industrial College of the Armed Forces,National Defense University,Fort McNair,Washington,DC,20319-5062**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**29**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

SPACE INDUSTRY 2006

ABSTRACT: The United States space industry is a product of Government necessity born of national security imperatives. From its inception, space has provided competitive advantages to the United States in terms of national security, national pride, and technological superiority. Unfortunately, our favorable position is eroding and in some areas, we are losing our competitive advantage. Lack of unified Government leadership, restrictive US trade policies, scarcity of critical systems engineering skills in the workforce, and emerging commercial and entrepreneurial activities are creating both obstacles and opportunities in a complex market environment. Establishment of comprehensive national space policy and a coherent leadership structure in conjunction with a critical review of current export policies is necessary to ensure the health of this vital industry. As a customer, regulator and advocate, the Government must take appropriate steps to promote favorable global trade conditions in and reaffirm US leadership.

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Domestic

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Boeing Satellite Development Center, El Segundo, California
Digital Globe, Longmont, Colorado
Lockheed Martin, Atlas V Space Flight Operations Center, Cape Canaveral, Florida
Lockheed Martin, Atlas V Production Facility, Waterton, Colorado
NASA Goddard Space Flight Center, Greenbelt, MD
NASA Kennedy Space Center, Florida
National Geospatial-Intelligence Agency, Washington, DC
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Orbital Sciences Corporation, Dulles, Virginia
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European Aeronautic Defence and Space Company (EADS) Astrium, Toulouse, France
EADS Space Transportation, Les Mureaux, France
EADS Space Transportation, Ottobrunn, Germany
Euroconsult, Paris, France
European Space Agency (ESA) Headquarters, Paris, France
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Surrey Satellite Technologies Limited, University of Surrey, Guildford, United Kingdom

ICAF In-Class Visits

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Department of Commerce, Washington, DC
Futron Corporation, Bethesda, MD
Mobile Satellite Ventures, Reston, Virginia
Satellite Industry Association, Washington, DC
White House Office of Science and Technology Policy, Washington, DC

INTRODUCTION

Space systems, and the products and services provided by space-based systems are a ubiquitous part of our American, and indeed global, society. From a national security perspective, the military's reliance on space systems is well known. Fifteen years ago, Operation Desert Storm demonstrated the military advantages space systems brought to the battlefield. From early detection of enemy missile launches provided by the Defense Support Program (DSP) satellite system, to geolocation capabilities provided by the Global Positioning System (GPS) that enabled large-scale maneuver over featureless desert terrain, space systems are now integrated into all aspects of military operations.[1] On the civil Government front, the President's Vision for Space Exploration has challenged a new generation of scientists, engineers and astronauts to continue the exploration of space begun during the Apollo era.[2] Finally, commercial space products and services, from satellite television and telephone services to point-of-service financial transactions generate revenue in excess of $100 billion in the global economy.[3] While space systems may not be a highly visible part of our everyday lives, the impact of these systems is tremendous.

The purpose of this study is to provide a method for the students listed above to synthesize the knowledge and experiences gained over the course of the year at the Industrial College of the Armed Forces. By selecting an industry critical to national security, in this case, the space industry, and applying lessons aimed at resourcing national strategy, this paper will define the industry, assess the current conditions and postulate the industry outlook. Additionally, this paper will describe the role of government in the space industry, identify specific challenges facing the industry and provide recommendations to mitigate the negative effects of those challenges.[4]

The students making up this industry study seminar possess various levels of experience with space systems. Some are new to the industry while others have years of space system acquisition or operations experience. While experience in the industry is helpful, fresh perspectives from individuals uninfluenced by previous experiences frequently highlight issues overlooked by those closer to the problems. The methodology used for the study consists of information gathered through presentations from senior industry representatives and site visits to selected companies, agencies and infrastructure locations. The selection of data sources was intended to be representative of the breadth of the domestic space industry and augmented by visits to European locations to gain an appreciation for the international space market. In the domestic and European industries, we recognize the influence of other major space players, such as Russia, China and India, but due to resource and time limitations, were unable to gather first hand data.

As a point of departure in looking at the space industry, one must understand three underpinning attributes of space systems: they are expensive and technically complex, and must work the first time. These simple facts explain a great deal about the character of the industry.

THE INDUSTRY DEFINED

Defining the space industry is not as easy a task as one may presume. Some choose a very narrow view of the industry while others attempt to be inclusive of firms

marginally related to space. Jeff Faust, the editor and publisher of The Space Review, stated that

> *"[i]n an effort to make the [space] industry look as big as possible, people often include as many … companies as possible. [T]hey include a number of companies that … shouldn't really be … part of the space industry, companies like Intelsat, Space Imaging, and XM Satellite Radio."*[5]

The purpose of defining an industry is to set the boundaries for meaningful analysis. According to Michael Porter, "[s]tructural analysis, by focusing broadly on competition well beyond existing rivals, should reduce the need for debates on where to draw industry boundaries".[6] Most industry reports produced by professional services use the North American Industry Classification System (NAICS) to define specific industries. For the most part, the space industry is a subset of NAICS code 33461 (Aerospace Product and Parts Manufacturing in the US) and represents only a 13% share of this market.[7] As such, the resultant data is heavily biased toward the aircraft industry and does not provide meaningful insights into the performance of the space industry. This narrow view of the space industry is consistent with Faust's position above.

Another common framework used to define the space industry is a matrix depicting two sets of elements: sectors and segments. Sectors are the markets served by space-based products and services and segments are those functions necessary to employ space capabilities. The three sectors are National Security Space, which includes defense and intelligence related space activities; Civil Space, whose primary customer is NASA, but includes all other non-defense Government space activities; and Commercial Space.[8] The three segments are satellite manufacturing; launch vehicle manufacturing and launch services; and satellite operations and services. The segments in this framework roughly correspond to the classic structure as contained in the NAICS. The sectors and segments are inextricably linked. Satellite operations cannot take place without satellites that cannot function until launched into an operational orbit; none of which would have meaning without customers. Government policies and regulations directly affect the nature of the commercial market, while Government demand drives investments and technology development. New technologies – commonly called spin-off technologies – eventually transfer new capabilities back to the commercial market. The classic structural view, as well as that espoused by Faust however, does not adequately describe these interrelationships and the economic impact that the space industry has domestically as well as globally.

National Security Space and Civil Space are the primary drivers of the US space industry.[9] From a purely structural view, US Government spending (both National Security and Civil) on space systems in 2004 totaled $35.778 billion.[10] This represents a mere 1.6% of the 2004 federal budget or 0.3% of the 2004 GDP. These figures do not come close to the value provided to the nation in terms of national security, national pride, and technological advances. Nor do they account for the revenue generated by commercial firms that primarily or exclusively use space systems. Direct-to-Home satellite services alone, such as DirecTV, generated over $18.5 billion in revenue in the United States in 2004.[11]

For the purposes of this study, it is necessary to view the space industry holistically. The interconnected nature of the sectors and segments along with a growing

commercial market demand an integrated approach. Therefore, the space industry is defined as those companies that provide space products and services to the sectors described above. This includes companies whose revenue is generated primarily through the use of space-based systems. It also includes international joint ventures, such as Sea Launch, LLC and International Launch Services, whose largest share owners are American firms. Each of the industry segments (satellite manufacturing, launch vehicle manufacturing and launch services, and satellite operations) face unique conditions and influences within the industry; therefore each will be examined separately within the context of the larger industry. It is only from this holistic perspective that we can derive meaningful analysis and truly understand the impact of the space industry both domestically and internationally.

CURRENT CONDITIONS

A Highly Concentrated, Competitive Industry

In order to appreciate the current condition of the space industry, it is necessary to review some significant events of the recent past. The domestic space industry, as stated earlier, is primarily driven by the Government. The spate of mergers and acquisitions in the defense industry during the 1990s, resulting from a decline in Government demand, consolidated the domestic space market into three primary competitors: Lockheed Martin, Boeing, and Northrop-Grumman. At the time these mergers were taking place, two other forces were shaping the space industry. The first was an expectation of a booming commercial satellite telecommunications market consisting of satellite constellations in low- and medium-earth orbits that would provide voice and data communications to millions of customers worldwide. Given this prediction, the space launch segment of the industry began preparing for a significant increase in demand for launch services. The US Government recognized an opportunity to develop new launch vehicles for both Government and commercial use based on the forecasted demand. As one of what was to be many customers, the Government planned to leverage the forecasted commercial demand and achieve cost savings by buying commercial launch services as just another customer. Unfortunately, the demand for services provided by these proposed telecommunications systems did not materialize resulting in bankruptcy for several firms and a sharp reduction in demand for launch services.

The second force, also during the 1990s, that had a significant impact was a change in the space systems acquisition strategy used by the Department of Defense. The premise of the new approach to space systems acquisition was that the commercial space market had become sufficiently mature such that contractors could now assume more of the technical and systems engineering risks. The Government reduced or eliminated traditional programmatic oversight in order to achieve cost and human capital savings. This approach, called Total System Performance Responsibility (TSPR), shifted programmatic risk almost entirely to the contractor by removing many of the reviews required by traditional oversight processes. In order to meet cost and schedule goals, contractors streamlined testing and other mission assurance activities. As a result of this approach, the Government acquisition workforce lost a generation of expertise in systems engineering; satellite programs began to experience technical failures and programmatic problems later in the acquisition cycle requiring greater commitment of resources to

correct problems.[12] The confluence of these three factors – consolidation of the industry, a commercial market that failed to materialize, and a major change in acquisition strategy – resulted in a highly concentrated and very competitive industry[13]. The following sections describe how the current conditions influence each of the space industry segments.

Satellite Manufacturing

Increasing Government budgets in both the National Security and Civil Space sectors have helped the industry to recover from the telecommunications bust of the 1990s and stabilize the manufacturing base. The National Security sector is in the process of recapitalizing many of the space systems that performed so well during the Cold War era with new, very expensive and highly complex satellite programs. The three primary competitors (previously mentioned) are the prime contractors or lead system integrators for nearly all National Security programs. Unfortunately, many of these programs such as the Future Imagery Architecture, the Transformational Satellite Communications System, Wideband Gapfiller, Advanced Extremely High Frequency Satellite, and Space-Based Infrared System-High are experiencing significant technical difficulties, cost overruns, and schedule delays. Reasons for the difficulties vary, but the Government Accountability Office (GAO) found that DOD was "… unable to match resources (technology, time, and money) to requirements before beginning individual programs, setting the stage for technical and other problems, which lead to cost and schedule increases."[14]

The commercial satellite manufacturing segment is experiencing strong competition and relatively low profit margins in the global market. In this segment, the three primary competitors serve as prime contractors or system integrators for many of the larger satellite orders. However, demand for commercial satellites is trending away from the larger more complex satellites. Many of the satellite operators are focusing on replenishment or filling gaps in their current capabilities, creating opportunities for smaller firms such as Space Systems Loral, Orbital Sciences Corporation, and Ball Aerospace to enjoy success in their chosen markets. Space Systems Loral, for example, competes almost exclusively in the geostationary communications satellite market. In the last five years, Space Systems Loral won contracts for fifteen geostationary communications satellites.[15] In the same period, Orbital Sciences Corporation, which competes as the world's leading manufacturer of smaller, more affordable satellites, delivered thirteen geostationary communications satellites to its customers.[16] A quick review of commercial satellite orders shows a strong tendency for customers to remain with the same satellite manufacturer for future orders. However, XM Satellite Radio recently awarded a contract for its fifth geostationary broadcast satellite to Space Systems Loral rather than Boeing, which built the first four satellites for XM.[17] This is an excellent example of the strong competition that currently exists in the commercial satellite manufacturing market and the influence one customer can exert over the suppliers.

Launch Vehicle Manufacturing and Launch Services

The launch vehicle manufacturing and services segment is dominated domestically by Lockheed Martin and Boeing. For National Security sector customers, these two manufacturers produce the Atlas V and the Delta IV families of launch vehicles. Each of these launch vehicles was developed and designed under a US Air Force program known as the Evolved Expendable Launch Vehicle (EELV) during the time that the demand for launch services was expected to boom. Initially, the EELV program was to down-select to one launch vehicle provider, but based on the US Space Transportation Policy, which articulates an assured access to space capability, both contractors were awarded launch contracts in order to maintain this critical national capability.[18] Both programs were very successful in designing exceptionally capable families of launch vehicles able to lift a variety of payloads; however, the commercial demand for these services did not materialize, resulting in significantly higher unit costs for each of these vehicles. As a result of the low demand, Lockheed Martin and Boeing announced a plan to merge their management and production lines for these vehicles under the name United Launch Alliance (ULA). The merge is expected to save the Government approximately $100 million per year while maintaining two distinct launch vehicles consistent with policy. This proposal is currently under anti-trust review by the Federal Trade Commission. It is also noteworthy that a potential entrant to the domestic space launch industry, Space Explorations Technologies (SpaceX), has filed suit to block the merger. SpaceX has plans to produce a launch vehicle that will compete directly with the Atlas V and Delta IV and views the ULA merger as anti-competitive.[19]

Orbital Sciences Corporation also manufactures a family of launch vehicles consistent with their business strategy of supplying the smaller, less expensive market. Orbital's Pegasus, Minotaur and Taurus launch vehicles provide space access for smaller payloads for their National Security, Civil and commercial customers.[20] A more detailed discussion of the proposed United Launch Alliance and its implications for the industry follows in the essays on major issues section of this paper.

Competition in the launch vehicle manufacturing and launch services segment has been very strong in recent years due to lower demand for satellite launches and excess capacity within the launch vehicle manufacturing industry.[21] The imperative for each space faring nation, or in the case of the European Space Agency (ESA) group of nations, to maintain an independent, assured capability to access space ensures an ever-increasing number of launch providers. Given recent market conditions, launch service providers created teaming relationships with complementary providers in order to cut costs and compete across the entire breadth of the launch market. For example, in 1995 Lockheed Martin joined with Khrunichev State Research and Production Space Center in Russia to create International Launch Services; also in 1995, Boeing formed Sea Launch, LLC with Ukranian, Russian, and Norwegian partners. Both of these joint ventures sought to leverage the best capabilities of each company while lowering costs, thereby improving their competitive advantage in the market.

Satellite Operations and Services

The satellite operations segment of the space industry includes companies whose revenue is generated from the operation of satellites or provision of products and services

primarily through space-based systems. This is the revenue generating part of the industry. Recent consolidation with the satellite communications market resulted in the top two companies accounting for nearly 40% of the market's total revenue. Intelsat acquired PanAmSat and SES Global acquired New Skies Satellites. These fixed satellite service providers generated nearly $10 billion in revenue in 2004. Significant growth in the satellite services market is now coming from direct broadcast services, such as DirecTV. Revenues from the direct broadcast service market grew nearly 300% since 1996 bringing in over $60 billion in 2004.[22]

International Competition

> *"Ultimately, nations succeed in particular industries because their home environment is the most dynamic and the most challenging, and stimulates and prods firms to upgrade and widen their advantages over time."*[23]

Three common themes characterize the international space industry: strong government involvement, teaming relationships between companies and countries, and specialized technical competencies. The first space faring nations, Russia, the United States, and France, started their space programs in conjunction with strategic deterrence forces in the form of intercontinental ballistic missiles. Governments then were the solitary drivers for technology development and the formation of an industrial base. Space systems became a symbol of national power and enabled nations to exercise sovereign rights in the global commons of space. Although our study concentrated on domestic and European space industries, influences from Russian, Chinese and Indian space programs were observed throughout our visits.

The United States and Europe have chosen two distinctly different strategies to achieve a competitive advantage in space systems. In the US, technology is the source of our competitive advantage and each firm in the industry attempts to differentiate itself through specific technical competencies. Companies develop these competencies through a mix of independent research and development and Government-funded efforts; the resulting technologies then may become proprietary to that company. In Europe, technology development is driven and funded by governmental space agencies, such as Centre National d'Etudes Spatiales (CNES) in France, or the intergovernmental European Space Agency (ESA). Once technologies are developed, they are transferred directly to industry. The ESA Industrial Policy states that member nations will receive at least a 90% return on the funding they provide to ESA; this policy guarantees the development of a space industry within member countries. This technology development approach also provides opportunities for firms within member nations to specialize, since the new technology is typically given to the contractor with the greatest experience in that particular area, ensuring a strong position in the market. An engineer from EADS Space Systems explained how his company had constructed world-class radio frequency test ranges, modeled from their test range in Ottobrunn, Germany, for customers in China and India. While this approach may not satisfy those in the US concerned with potential technology transfer issues, it has accomplished two things for EADS: first, they are able to market world-class products to international customers and second, the revenue stream generated by these sales enables investments in future technological innovations.[24]

CHALLENGES AND OPPORTUNITIES

US Government Leadership

The relationship between Government and industry significantly influences the behavior of the firms within the various markets. Government leadership in this area has been inconsistent over the last two decades. During the Reagan Administration, the executive branch exercised leadership in space through a Senior Interagency Group for Space (SIGSPACE). President George H. W. Bush established the National Space Council to provide leadership in Government space policy. The Clinton Administration delegated this responsibility to the White House Office for Science and Technology Policy. The current Bush Administration uses a Policy Coordinating Committee within the National Security Council System to address space issues.[25] Clear direction from the Executive Branch, coordinated across services and agencies, is necessary to ensure efficient allocation of resources consistent with national space policies.

In the National Security Space sector, the 2001 effort of the Commission to Assess United States National Security Space Management and Organization (also called the Rumsfeld Commission) recognized the need for a single focal point for Government leadership. One of the Commission's recommendations called for the establishment of a single individual to coordinate both defense and intelligence space programs. Although this recommendation was rapidly implemented, it has since been reversed returning the National Security space sector to the uncoordinated acquisition position that existed prior to 2001. Many of the Government and industry representatives we visited view this as a major step backwards.

Export Controls Stifling US Competition

The current export control regime was a consistent theme among space industry representatives both domestically and internationally. For domestic firms, export controls result in a reduction and in some cases elimination of their ability to compete in the international market.[26] A detailed discussion of export controls follows in the essays on major issues section of this paper.

Space Industry Workforce

The "graying" of the space industry workforce has been a consistent theme over the last several years.[27] While the average age of the space industry worker may be increasing, we found that the industry is not having exceptional difficulty attracting young engineers. Rather, the key issue in the workforce is development of systems engineers – those engineers capable of working across disciplinary boundaries in order to effectively integrate many complex systems.[28] The key to developing systems engineers is experience that comes with working on several programs over time. Given the current highly competitive nature of the industry, fewer programs are in development – offering fewer opportunities for engineers to gain experience. Additionally, competition encourages companies to seek out the more experienced engineers enticing many engineers to change companies approximately every five years. This shifting of human capital compounds the difficulties in developing systems engineers.[29]

Commercial and Entrepreneurial Activities

Emerging commercial and entrepreneurial activities are attempting to create new markets such as commercial space transportation services and space tourism. NASA recently released a request for proposal for a Commercial Orbital Transportation System to replace current Government programs with commercial providers. Space tourism companies like Virgin Galactic, energized by Scaled Composites SpaceShip One winning the Ansari X-Prize, will begin offering suborbital flights for adventurous tourists by the end of the decade.[30] A more detailed discussion of the commercialization of space follows in the essays on major topics section of this paper.

OUTLOOK

The outlook for the domestic space industry indicates slow and steady growth in the near term. Increasing Government expenditures in the National Security and Civil space sectors and replenishment of commercial satellite systems, all point to steady demand in the next 5 years. Additionally, increasing numbers of subscribers in the Direct Broadcast market should start producing profits for the firms in this market in the next 2-3 years.

Several wild cards could drive a surge in demand in the longer term. There is a potential for new demand in commercial transportation services and space tourism; however, given the current overcapacity in the industry, large investments in infrastructure will not likely be necessary to meet higher demand.

Finally, a US Air Force initiative, called operationally responsive space, seeks to employ space systems on short notice in support of military operations. This initiative looks to capitalize on miniaturization of satellite technology to build capable, low-cost satellites and utilize small, low-cost launch vehicles, such as the Falcon I being developed by Space Exploration Technologies, to place militarily useful space applications in orbit for a specific operation. If this concept comes to fruition, it could generate greater demand for producers currently serving the smaller niche markets such as Orbital Sciences and Surrey Satellite Technologies.

GOVERNMENT GOALS AND ROLE

The space industry is a child of government necessity. Although certain markets within the space industry, such as geostationary communications services, can be categorized as mature markets, the commercial market does not yet dominate the industry. Governments continue to play the most influential role in the industry as a regulator, customer, and advocate.

When asked about the Government’s role in the domestic space industry, nearly every industry representative expressed frustration with restrictions related to exports of space technologies. Currently, technologies related to satellites and launch vehicles are listed on the United States Munitions List and are regulated under the International Traffic in Arms Regulations (ITAR) by the Department of State. While the same industry representatives understand the rationale for this regulatory arrangement, they believe a more balanced approach will allow domestic firms to be much more competitive

internationally without transferring critical technologies. The greatest competitive advantage US firms possess is technology; by imposing delays associated with export reviews and restricting our technologies from the international market, our policy places US firms at a significant disadvantage. Although the direct economic impact is difficult to calculate, one estimate identifies a loss of satellite orders ranging from a $1.5 to $3.0 billion loss to the US economy.[31] These restrictions place an undue burden on the domestic space industry, reducing our ability to compete and innovate in the global market.

As the largest customer in the space industry, the Government provides the economic capital necessary to maintain adequate industry capacity and prompt innovation. Unfortunately, unstable Government funding and changing requirements continue to cause problems in many of the Government's most expensive space acquisition programs.[32]

As an advocate, the Government's current National Space Policy states that "…[t]he fundamental goal of US commercial space policy is to support and enhance US economic competitiveness in space activities while protecting US national security and foreign policy interests."[33] As the following essay indicates, the balance between economic competitiveness and protection of US national security is out of balance.

Although the Government has many opportunities to improve its role as a regulator, customer and advocate, the universal opinion from industry representatives was that the relationship between Government and industry is favorable.[34]

ESSAYS ON MAJOR ISSUES

Export Controls

US export control policy related to commercial satellites and associated technologies vacillated between extremes in the mid to late 1990s. The following paragraphs will describe the environment as it existed during distinct time periods, explain the roles and responsibilities of US Government agencies, and elaborate on some of the rationale for certain policy actions.

Prior to 1996, the US Department of State (DoS) was responsible for oversight of the "United States Munitions List" (USML) and compliance with "International Traffic in Arms Regulations" (ITAR). Concerns that exported technology might enhance foreign military capability mandated that commercial satellites and associated technologies be classified as "munitions," included on the USML, and thus subject to ITAR.[35]

Concurrent with export license applications, US companies were required to process Requests for Proposals (RFP) from customers and negotiate Technical Assistance Agreements (TAA) that satisfied DoS requirements before engaging in technical discussions with foreign entities. Obtaining DoS export licenses or exemptions and negotiating TAAs that met stringent DoS requirements was a time-consuming, complicated process. Proposed USML export licenses required Congressional, US Department of Defense (DoD), and Director of Central Intelligence review, and could also require National Security Agency review. No definitive timelines for this review existed.[36]

The US Department of Commerce (DoC) oversaw the Commerce Control List (CCL) and compliance with "Export Administration Regulations" (EAR). The CCL

consisted of items not classified as munitions but considered sensitive technology or "dual-use" industrial products. CCL export licenses or exemptions did not require Congressional review and all actions were to be completed within 90 days.[37]

The DoC process was – by design – less stringent than the DoS process because DoC licensed products did not involve our most advanced, "cutting edge" technologies. Whereas the focus of the DoS licensing process was maintenance of national security, the focus of the DoC licensing process was promotion of international trade. The DoC export license and exemption process was less time-consuming, less complicated, and more definitive.[38]

In March 1996, following interagency review, the Clinton Administration shifted responsibility for commercial satellite technology from DoS to DoC. Although commercial satellites might employ potential dual-use technologies, the thought was they should not automatically be categorized as "military" items. Their intended use should determine whether they were considered "military" items and therefore subject to DoS's more stringent licensing process.[39] Two factors influenced the Administration's decision to shift control from DoS to DoC:

> "1. To make the US commercial satellite industry more competitive in the global market by subjecting them to the less stringent DoC export licensing requirements.
>
> 2. To entice China to tighten its controls on missile technology exports by advocating increased US/China commercial space cooperation."[40]

In the summer of 1998, the US Government fined Loral Space and Hughes Electronics for inadvertently transferring restricted technical information to China while assisting in the failure analysis of two earlier launch attempts. Opponents of the Clinton Administration's revised export policy contended that the transfer of restricted information would not have happened under the more stringent DoS export licensing process. Likewise, critics of the Administration's engagement policy with China used this incident for political gain and attacked the Administration as "soft on China." They also argued that relaxed export controls and greater involvement in China's commercial space sector ventures benefited China's military space and ballistic missile programs and threatened US national security.[41]

Consequently in the fall of 1998, Congress enacted the National Defense Authorization Act for FY 1999. This legislation reversed the Clinton Administration's 1996 policy and returned export control of commercial satellite technology to DoS.[42]

Advantages and Disadvantages of Current Policy. Proponents of the current policy propose that the more stringent reporting, licensing, and oversight requirements provide tighter export controls. Theoretically, these controls afford greater protection against unauthorized release and subsequent foreign exploitation of sensitive commercial satellite technology that might improve foreign ballistic missile capability, thus negatively affecting US national security.[43]

Opponents characterize the current policy as cumbersome, time-consuming, and politically-charged and cite several disadvantages. First is the negative financial impact on the US commercial space industry that manifests itself in several ways:[44]

> "1. Potential failure to secure timely export licenses and subsequent withdrawal from negotiations may make foreign firms reluctant to commit to US suppliers if

an adequate non-US source for satellites, components, and technology is readily available.

2. US suppliers incur significant financial penalties for late deliveries.

3. DoD and Government purchases – once considered the bedrock of the satellite industry – have fallen off to 35% of sales in comparison to 1990 when they represented 50% of sales. This decline has forced US companies to depend on commercial sales – including exports – for the bulk of their business. Commercial sales may suffer as a result of current export control policy.

4. The commercial satellite market has tripled in size since 1992. Satellite production timelines have decreased from 2 to 3 years to 18 months and RFP response timelines of 30 days are not uncommon. US manufacturers face the prospect of inordinate license delays that drive inability to meet customer demands; that hurts competitiveness in the expanding world market.

5. Lack of predictable, timely supply drives foreign manufacturers to avoid using US parts/components; there is a trend to "design out" US satellite components."[45]

The net result of the aforementioned factors is that US suppliers may be losing market share to foreign competitors.[46]

Second is the negative impact on the science and engineering workforce. The Satellite Industry Association (SIA) claims that 25,000 high-tech manufacturing jobs may be lost over the next 10 years because of current US export control policy and migration of business to foreign competitors who operate under less restrictive policies. Job loss is not the only issue; the long-term health of our high-technology "intellectual capital" may also be in jeopardy. More senior, highly experienced scientists and technicians may seek other employment opportunities or choose retirement in the face of declining requirements for their services based on inadequate business opportunities.[47]

Third is the "unintended consequence" of tighter export control policy that ultimately jeopardized national security. Inability to secure US technology in support of their own endeavors has forced other nations to accelerate their domestic R&D programs and improve cooperative efforts that exclude the US in the global economy. The net result is the US is no longer the "sole-source" provider for many critical satellite technologies.[48] Unfortunately, harsh export control policy – specifically designed to protect US national security – has actually eroded the dominant position the US previously maintained.[49]

Observations. Although US satellite technology holds a qualitative edge, the margin is decreasing as foreign governments aggressively promote aerospace development and foreign firms exploit the gap harsh US export controls create.[50] Previous technology compromises by US companies were the result of alleged illegal acts that subverted US export control policy, not the policies themselves.[51] Many satellite technologies comparable to those produced by US firms are available outside the US market, and US firms are losing market share to foreign firms.[52]

Recommendations.

"1. Alter statutes to transfer commercial satellites from the USML to the CCL…with appropriate procedural safeguards to address discrete national security concerns.
2. Remove technically equivalent items from the USML that are commercially available from NATO allies, Japan, or Australia to permit US firms to compete on an equal basis.
3. Establish/maintain specific timelines for export control processes that reasonably conform to customer expectations and requirements in the global marketplace.
4. Extend license consolidation and expedited license approval procedures implemented September 1, 2001 for NATO allies, Japan, and Australia to major non-NATO allies and other countries as appropriate, as soon as possible.
5. Establish/maintain adequate staffing/funding for all USG export control functions to ensure these functions occur within timelines that support the commercial space industry.
6. Establish a process for reviewing responsibilities of all USG entities performing export control-related functions on a periodic basis.
7. Formulate/execute a comprehensive approach to export control that achieves the overarching objective of safeguarding US national security."[53]

Conclusions. Assuming that adequate safeguards are in place to address national security concerns, sales of satellites and associated equipment that are commercially available outside the US should not be restricted. Easing restrictions will create a more level playing field for US manufacturers and help stabilize the precipitous decline in global market share the US experienced after the return to the pre-1996 export control policy.

Unfortunately, the politically-charged post-9/11 environment is not conducive to change where proponents of that change might be perceived as "soft on security"; therefore, any near-term change in our current satellite export-control policy is not likely. Safeguarding sensitive satellite technologies in order to preserve our security is appropriate; however, the pendulum has swung too far in favor of protectionism and our judgment is clouded by politics and "perception" vice the reality of the global economic and security environment. Our Government policy must become more objective and base our satellite technology export control decisions on the merits of each case.

--Lieutenant Colonel Raymond T. Strasburger, USAF

Commercialization of Space

The US Government is nurturing the nation's scientific and engineering communities through its investment in space. According to the US Space Transportation Policy, the US Government, particularly the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD), "… must provide sufficient and stable funding for the acquisition of US space transportation capabilities in order to create a climate in which a robust space transportation industrial and technology base can flourish".[54] A discussion of the responsibilities and initiatives of these Government organizations with regard to the commercialization of space follows.

Federal Aviation Administration (FAA). Space launch and reentry sites, often called spaceports, are the nation's access points to and from space and are essential for assuring US access to space. The first spaceports in the US were built and operated by the Government to meet a variety of national security needs beginning in the 1940s, but later in the century, the US Government believed that the demand for spaceports would overwhelm the nation's federal capacity. In 1984, as authorized by Executive Order 12465 and Title 49 of the United States Code, the FAA's Office of Commercial Transportation (FAA/AST) was given the responsibility to license and regulate US commercial space launch and reentry activities and for the operation of these non-federal launch and reentry sites.[55] The California Spaceport was the first commercial spaceport to be licensed in 1996 with the first launch occurring in July 2000.

The commercial spaceports are funded primarily by individual states, but private sponsorship and federal assistance supplement the state funding. Since 1996, the FAA/AST has licensed an additional four non-federal launch sites with another six proposed. Three of these commercial spaceports are co-located with federal launch sites. Although the number of commercial payload launches is anticipated to continue to rise in the future, the commercial space industry boom that was originally forecast for the turn of the century has yet to materialize. As of 2004, the number of government payloads worldwide still outpaces commercial payload launches.[56]

National Aeronautics and Space Administration (NASA). Under <u>The President's Vision for Space Exploration,</u> published in January 2004, NASA has responsibility for the manned exploration of the Moon and Mars, as well as maintaining a constant presence at the International Space Station (ISS). In order to meet these objectives, NASA will be retiring the current space shuttle by 2010 and replacing it with the next generation of reusable launch vehicles. The Crew Exploration Vehicle (CEV) is the NASA program aimed at designing and building the next manned vehicle. In 2005, the competition was narrowed from eight competitors to two: Lockheed Martin and the joint Northrop Grumman – Boeing team. NASA hopes to select the CEV winner by mid-2006 in order to have an operational, manned vehicle ready to send to the moon by 2012. The initial contract to the two competitors was $56 million for the initial concept and design phase.[57]

With the imminent retirement of the space shuttle by 2010, combined with the limited number of upcoming space shuttle flights, the US finds itself in the vulnerable position of relying on international space vehicles to reach the ISS. The US would like to have an American provider available to complete the construction of the ISS and to refresh the ISS supplies. Therefore, in December 2005, NASA released a draft request for proposals (RFP), under the Commercial Orbital Transportation Services (COTS) program, to commercially buy cargo services to the ISS and as a second phase, support a manned crew to and from the ISS. NASA has anticipated funding the cargo vehicle transport phase of the COTS program for approximately $500 million.[58] Because of the US desire to support the US commercial industrial base, the COTS program requires that the bidding companies have at least 50 percent US ownership.

Department of Defense (DoD). In the early 1990s, the DoD decided to develop an affordable alternative to the existing medium- and heavy-lift launch vehicles (i.e. Titan, Atlas, and Delta II). The Air Force-led program, Evolved Expendable Launch Vehicle

(EELV), was contractually awarded to Lockheed Martin and Boeing in October 1998 with funding totaling approximately $3 billion. The goal of the program was to standardize payload interfaces, launch pads, and off-pad processing (DefenseLINK News, 1998). The more strategic goal of the EELV program was to stimulate the commercial launch industry since it was poised to provide a more affordable and reliable access to space to meet both the military and commercial space lift requirements. The Government felt that with two US commercial launch vehicle families, the US industrial base would be enhanced and allow greater competition in the international space market. The EELV program did result in the creation of Lockheed Martin's Atlas V and Boeing's Delta IV launch vehicles, both having carried Government and commercial payloads since 2002.

In addition to providing Government funding to a multitude of US commercial space companies, the DoD operates most of the federal spaceports. The Air Force is responsible for the operation of the two largest federal launch sites, Cape Canaveral and Vandenberg. These launch sites support national security and civil sector, as well as commercial launch needs. Due to the aging infrastructures at these launch sites, the Government has undertaken a range modernization effort, which is again contributing large amounts of money into the commercial space industry.

Space Competitions. History has demonstrated that competitions are a mechanism for stimulating innovation, and today we are observing that truth. A number of space competitions are driving innovation and new technology into the space arena. The three major space competitions are the X Prize Cup, the America's Space Prize, and the Centennial Challenges Program, each seeking slightly different objectives but supportive of the overall goal of having affordable, quality, and efficient space launch capabilities

The X Prize Cup is the second competition sponsored by the X Prize Foundation, founded in 1995 by Peter Diamandis after reading the Spirit of St. Louis and realizing that the entire aviation industry was initially spurred by aviation prizes. Mr. Diamandis held a lifelong desire to travel into space and decided to create a cash prize. With lots of private funding and the support and encouragement of NASA, the first X Prize competition with a $10 million prize was announced in a press conference in 1996.

The America's Space Prize is worth $50 million, valid through 10 January 2010, to the first US entrant to produce a privately funded, reusable vehicle capable of carrying five people into two consecutive 240-mile orbits. Half of the $50 million will be paid personally by Robert Bigelow with the remainder paid by Bigelow Aerospace.[59] The winning reusable vehicle is anticipated to provide options for servicing the inflatable space habitats that are under development by Bigelow Aerospace.

NASA has also entered into the space competition arena with the Centennial Challenges program designed to support technical innovation. In support of NASA's goal of returning to the Moon by 2020, cash prizes will be awarded for technologies contributing to NASA's mission.

Economic Impact. Commercial space transportation has had a large economic impact on the US economy over the past several decades and has influenced industry segments such as launch vehicle manufacturing, satellite manufacturing, and satellite services. Although each of these segments has not seen uniform growth since 1999, the cumulative data shows that commercial space activities have increased. Beginning in 1998 with the first

US commercial launch of the Sirius 1 communications satellite, the commercial space transportation industry has fostered the evolution of new communications markets such as direct-to-home television (satellite TV) and digital audio radio services (satellite radio). It is these satellite services industries that have shown a dramatic increase, from 25.8 % of the commercial space transportation market in 1999 to 56.5% in 2004.[60] An 11% growth rate was seen in 2004 alone.

The launch vehicle manufacturing industry segment is slowly starting to rebound after the decline in the number of launches from 1999-2002. The launch vehicle manufacturing segment was roughly 5.7% of the commercial space transportation industry in 1999 compared to the .8% share in 2004.[61] Since 2002, the FAA has increased the number of licenses issued, which is indicative of the slow rebound in this industry segment.

Satellite services have seen the largest growth industry segment since 1999. The percentage of satellite services has risen from 42% in 1999 to 52% in 2004.[62]. Included in the satellite services industry segment are the consumer driven direct-to-home TV services, the very small aperture terminal services, digital audio radio service, satellite data services, and the mobile satellite telephony. In dealing with the aftermaths of the Tsunami and Katrina natural disasters, first-responders and relief workers were able to assess the damages and provide mobile communications to those affected. Due to effectiveness of satellite communications during the disaster recovery and relief phases, the US commercial satellite industry is pressuring Congress to classify satellites as one of our nation's critical infrastructure components. If this effort succeeds, many US satellite and satellite service provider's futures will be cemented.

Conclusion. The US Government is committed to preserving our nation's presence in space and is nurturing the nation's scientific and engineering communities to maintain its global leadership in science, exploration, and technological innovation. Just as President Kennedy pushed our nation in the 1960s, past and present US policies continue to drive the industrial base toward innovative and more efficient production. Lambakis could not have summarized better when he stated, "Through the development of new technologies and growth in commercial markets, civil space contributes to the US economy and the general prosperity of the nation".[63] Therefore, with the monetary support of the US Government, it is easy to prophesize that the commercialization of space is just in its infancy, and that many unknown technologies await us in the future.

--Ms. Jean Schaffer, NSA

United Launch Alliance

The use of "Space" has been a central part of United States (US) national security programs, scientific exploration efforts, and national economic power for over four decades. Central among these efforts has been the ability to maintain launch access through various space transportation capabilities. These efforts have produced tremendous feats such as the Saturn V rocket, the Shuttle Transportation System, and the military family of Atlas, Titan, and Delta launch vehicles. Yet despite all of these successes, changes in the world climate and changes in international markets now position the US launch industry in a uniquely weak position not seen in the history of this program. As stated in the January 2005 U.S. Space Transportation Policy, "A significant

downturn in the market for commercial launch services has undermined for the time being the ability of industry to recoup its significant investment in current launch systems and effectively precludes industry from sustaining a robust industrial and technology base sufficient to meet all United States Government needs." This same policy provides goals and objectives to help remedy these problems and assure access to space for security, civil, scientific, and economic interests.[64] While space access for all areas are intertwined and tough to separate, this essay will concentrate on recommendations specific to meeting the national security goals. To better understand these recommendations, a brief history of the launch industry follows that provides the context for the current direction and situation of US programs. With this history as a backdrop, our seminar recommends the US adopt the following multi-avenue approach to assist in meeting the national security goals of the US Space Transportation Policy: support the United Launch Alliance (ULA) in a manner that provides flexibility for future changes, continue support of the commercial launch industry to encourage innovation and cost reduction, work on both US and international trade regulations to increase the competitive nature of the US launch industry, and maximize cooperative efforts between military, civil, and commercial space launch.

Background and History. To understand how the current US space launch program came to be and how we derived our space transportation goals, it is important to understand the associated history. The first area of this history includes the shifting evolution of US efforts on launch vehicles between expendable and reusable vehicles. The second historical area covers commercial launch market projections and how they shaped the evolution of launch vehicles.

The US approach to launch has migrated between dependence on expendable vehicles, to re-usable vehicles, to a combination that now emphasizes assured access. During the early portions of the US space program, launch vehicle designs derived directly from ICBM efforts and were expendable. This changed in 1972 when President Nixon signed off on NASA's plan for a reusable launch vehicle and the Space Transportation System (STS), also known as the Space Shuttle, was born.[65] This decision promised assured and cheaper access to space for all segments of the space market, with national security in particular migrating almost exclusively to the use of the STS. As a result, commercial advancements in expendable vehicle technology lagged.[66] By 1984, the Air Force began to articulate the need for a complementary expendable vehicle to augment the STS, leading to the Titan IV program.[67] Yet because of the earlier de-emphasis on expendable vehicles, industry based this vehicle on previous designs. This all changed when the 1986 Challenger disaster exposed the flawed approach of using a single vehicle. Instantly, the US government scrambled to revive expendable programs and reinvigorate innovation in space launch. Unfortunately, the "shuttle-only" direction of the late 70s and early 80s had curtailed expendable vehicle technology before it fully matured and before any normally expected commercial innovation and exploitation could occur.[68] As a result, expendable vehicles following Challenger did not produce advances in performance or cost. In addition, there were few economic drivers to independently incentivize the industry. This situation eventually led to the 1994 Space Launch Modernization Study recommending pursuit of the Evolved Expendable Launch Vehicle (EELV) program to remedy expendable technology and provide assured access for national security space programs.[69] Given the experiences with Challenger and the loss of

technology advancement within industry, the main tenants of EELV became meeting requirements for assured access, reducing costs by 25%, and improving operability to allow more responsive launch and usage in the commercial sector.[70] While cost and assurance contributed, the largest driver shaping current U.S. direction in launch vehicles was the over-projection of the commercial market.

Beginning in 1997, the FAA's Office of Commercial Space Transportation and the Commercial Space Transportation Advisory Committee (COMSTAC) began to project a large market for commercial launches.[71] These projections were based on a booming telecommunications market likely to use satellite suppliers. Yet fiber optic, cellular, and other terrestrial communications methods emerged as more cost effective and reliable than satellite based communications. This evolution completely changed the projections and COMSTAC estimates for commercial launches have declined every year from 1997 until 2004. Current projections show an average of 22.8 worldwide commercial launches a year from 2005-2014. These estimates include 16.4 launches to geosynchronous and 6.4 launches to low earth orbit a year.[72] This represents a 50% reduction in actual launches versus predictions with some years reaching almost 70% reductions from original estimates. When you couple the drastic difference between these estimates and the actual launches with the pursued vehicle strategies, you have a recipe for the currently depressed US launch market. This historical context drives the recommended actions to help remedy this situation and achieve the national security portion of the US Space Transportation Policy.

Recommendations for Meeting National Security Goals of Space Transportation Policy. The US should support the ULA request while ensuring we maintain the flexibility to adjust to future changes. Based on the above history, it is clear our desire for assured access is partially responsible for the dual-contractor approach and over-capacity in the market. Absent other capable contractors and our desire to maintain a viable industrial base, we must ensure both contractors remain viable through the ULA proposal. The current ULA arrangement allows for separate production of both EELV versions to maintain assured access. Although, events such as the Boeing strike do point out assured access dangers when using a common workforce.[73] In addition, permitting the contractors to consolidate helps reduce operating costs for the Government and contractors minimizing the fixed cost losses the contractors suffered in their initial investments.[74] This may be the only economic model capable of keeping both companies viable in the space launch industry. Therefore, ULA support efforts should include ruling against lawsuits or challenges, such as those filed by SpaceX in October 2005, on the premise of national security interests.[75] While maintaining viability is one aspect of ULA support, flexibility to adjust to the market or augment the ULA as other commercial contractors become available is required to ensure we don't limit innovation. The current Air Force approach for awarding EELV launches annually, announced in September of 2005, provides some flexibility to award to alternate sources as available.[76] In addition, any temptations to lock up longer contracts to save money should be avoided to ensure we don't save money in the short term at the expense of long-term access issues. Long-term contracts lock out alternative approaches. Increasing support for these alternative commercial concepts can also help maintain flexibility.

Potential alternatives to current EELV providers that may produce lower cost solutions and innovative technologies must receive support. SpaceX, SpaceShipOne, and

Virgin Galactic are in the forefront of entrepreneurial efforts that promise reduced launch costs, increased reliability, and new areas of performance and access while requiring low levels of government funding.[77] This is evidenced by the recent SpaceX failure of the Falcon 1 launch vehicle costing the Air Force and DARPA only $8 million.[78] The value of these investments was evident in the continued support of several U.S. government contracts for a SpaceX launch signed after the failure of Falcon 1.[79] Other commercial efforts such as the Affordable Responsive Space Lift study contracts awarded to Northrop Grumman and three other yet released contractors provide promise for both improved launch costs and the satisfaction of the operationally responsive access to space objective contained in the Space Transportation Policy.[80] While Elon Musk's legal battle should be opposed since we need the ULA, the intent of forcing flexibility in our launch contracts to allow competition is on target and we must continue to invest in and support commercial efforts. In testimony before the House Committee on Space and Aeronautics in April of 2005, Elon Musk provided the following statement, "The most important thing that the government should do is adopt a nurturing and supportive attitude towards new entrepreneurial efforts." He then went on to say, "As for what government should not do, I think it is important to minimize the regulatory burden required for space launch activities".[81]This area of regulation must be addressed in conjunction with the other stated efforts to achieve the national security goals of the Space Transportation Policy.

Current trade regulations and policies hamper the competitive nature of the US launch industry and weaken the US's ability to provide assured space access. Foreign launch providers in Europe, China, Ukraine, and Russia all provide launch services for a lower price-per-pound to orbit than commercial EELV.[82] Given the previously discussed expectation regarding EELV dual use in the commercial sector, it is essential the US capture a portion of that market to remain viable and affordable in the national security sector. Given this existing price disadvantage, removing barriers to obtaining contracts becomes even more important. Current ITAR procedures often provide foreign businesses cause for concern. Whether these are real or just perceived concerns remains unclear, but even perceptions on the part of customers can be harmful when you are in a competitive market.[83] In addition, current trade restrictions do not allow for graduated approaches. While national security concerns are rightly paramount in these decisions, the treatment of all foreign governments as equals seems counter-productive. Similar to how we exchange intelligence information at different levels with different nations, ITAR regulations could be re-written to allow faster processing for some allies or partners. Cost disparities for launch services were also previously addressed through bi-lateral trade agreements. Negotiated deals with Russia, Ukraine, and China allowed for launches of US built commercial satellites in exchange for price controls and limits on the number of US satellites launched.[84] Unfortunately, these agreements ran out in 2000 and 2001 and new agreements have not been negotiated. While market dominance does not favor the US as much as it did when the original agreements were negotiated in the 90s, new agreements are worthy of effort to help protect and promote the US launch industry. This reduced market dominance also points out the need for increased cooperation both domestically and internationally to support the US launch industry.

As the US has lost its dominant position in the launch market, it has become essential to maximize cooperative efforts between military, civil, and commercial activities both domestically and internationally. Given the current over-capacity and

limited funding, leveraging cooperative efforts saves funding and improves industry viability. As such, NASA and DoD must be forced to comply with the guidance in the Space Transportation Policy emphasizing use of EELV and EELV derivatives to meet space exploration needs.[85] This type of cooperation should also be true with the entrepreneurial commercial companies, where NASA should jointly embrace SpaceX and other efforts with DoD since potential exists to leverage innovative technologies. To date, NASA has not committed to any launches on Falcon 1 despite DARPA and Air Force commitments.[86] In addition, foreign markets wary of US trade regulations will remain so unless we work cooperatively. Recent concerns over Chinese space progress hampers cooperative efforts on that front.[87] Likewise, on President Bush's recent visit to India, there was no mention of allowing them to launch US satellite payloads or of having some of their space agency centers lifted from export blacklists despite trade concessions to India and expected progress in this regard.[88] While national security concerns overshadow both examples, it illustrates the difficulties US launch manufacturers will have in attracting foreign business. Without some level of cooperation as an incentive, US manufacturers are unlikely to gain significant additional foreign business.

Conclusion. The US launch industry is in the most unique and weak period of its 40 plus year history. This resulted from a combination of miscalculations in strategy, reactions to launch failures, and changes in volatile market forecasts that have combined to produce excess launch capacity while also retarding innovation and technology. These combined factors have weakened the viability of the industry and called into question its ability to maintain assured access and meet the national security objectives set forth in the US Space Transportation Policy. While the US Space Transportation Policy provides some guidance to remedy this situation, four additional areas of emphasis can assist in this regard. These include supporting the ULA in a manner that provides flexibility for future changes and provisions that promote our ability to bring in innovative cost reducing alternatives to the current EELV as they become available. This coincides with the need for continued support of the commercial launch industry and other entrepreneurial efforts to encourage innovation and cost reduction. These efforts also support the eventual migration toward operationally responsive space launch capabilities. The third area of emphasis is on re-working both US and international trade regulations to remove barriers and increase the competitive nature of the US launch industry. Given the cost disadvantages of current US launch systems this task becomes essential to helping US firms gain the portions of the commercial market they need to remain viable and competitive. Finally, cooperation between military, civil, and commercial space launch efforts on both the domestic and international fronts must be emphasized. These cooperative efforts can save funding and open up currently closed markets to help increase the viability of the space launch technology and industrial base. While these efforts are not easy and in some cases not cheap, they are required to ensure the national security objectives established in the US Space Transportation Policy are fully satisfied.

--Lieutenant Colonel Brian T. Kelly, USAF

CONCLUSION AND RECOMMENDATIONS

The ability to operate in space is a vital national capability. In addition to the specific recommendations highlighted in the previous essays, our seminar agreed on the

following high-level recommendations. The extensive role of Government in the space industry demands consistency in the development and implementation of space policy. A single, permanent body within the Executive Branch representing National Security, Civil, and commercial space activities is essential to developing, promulgating and implementing coherent policy in order to achieve policy goals. A first step in this process within the National Security space sector is to reestablish the single focal point for space in accordance with the 2001 recommendation of the Rumsfeld Commission. If the current dichotomy continues, we will return to the redundant and inefficient situation of the past. The next step is the formation of an inter-sector organization given the responsibility and authority for space policy.

American competitive advantage in the space industry depends on our technological superiority. Yet it is exactly this source of our competitive advantage that is hampered by the current export control process. A critical review of the current export control regime is necessary to promote American competition in the global market through a more balanced approach to technology transfer concerns.

An educated and experienced workforce enables our vital space capabilities. Lessons learned over the past forty years, many through expensive and catastrophic failures, shaped the workforce and the way space systems were developed and acquired. The complex nature of space systems places a high demand on systems engineering skills. As we recapitalize many of our older systems, we must deliberately develop and protect our systems engineer workforce in both Government and industry. Systems engineering must be emphasized at the start of all new programs to avoid costly mistakes later in the acquisition cycle.

Finally, if the Government establishes clear and consistent leadership, promotes American competition in the global marketplace, and implements programs and incentives to nurture critical workforce skills, commercial and entrepreneurial space activities can then flourish in a favorable regulatory environment. In its role as advocate, the Government must create conditions that will enable a commercial space industry to flourish. The benefits of a mature commercial space industry may be difficult to predict, but drawing a parallel to the commercial aircraft industry may illuminate the possibilities. Entrepreneurs are on the verge of providing space services traditionally provided by government programs. Space transportation and tourism present exciting new opportunities for innovation in the space industry.

The United States space industry is exceptionally capable and robust. Its ability to meet national security requirements is unquestionable, however much can be done to improve the efficiency and effectiveness of the Government-industry relationship. Implementation of the above recommendations will go a long way toward reaffirming US leadership in the international space industry.

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